A scale break in high-resolution liquid water path measurements

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Introduction

At small scales Liquid Water Path (LWP) measurements are smoother than Liquid Water Content (LWC) measurement.

At scales equal or larger than the cloud depth the vertical variations are not averaged. LWP and LWC are identical. At, e.g., scales that are 10 times smaller than the cloud depth, the LWP will have less variance due to averaging. At smaller scales this averaging will be stronger. This thus produces a scale break in the LWP spectrum with a steeper slope at scales below the cloud depth.

4D CLOUDS BMBF/AFO2000

The 4D-clouds project aims at capturing the radiative influence of inhomogeneous clouds and at implementing these influences in dynamical atmospheric models.

Conclusions & Outlook

Conclusions

1) Measured LWP spectra show a scale break.
2) This scale break can be understood theoretically by the integration, which reduces small scale variance.

Speculations

3) Part of this effect will probably also explain radiative smoothing, next to horizontal photon transport.
4) It might be possible to retrieve cloud depth using this scale break.

Further work

5) Investigate the importance of vertical averaging on radiative smoothing.
6) Investigate influence of stability, which may cause anisotropies between horizontal and vertical correlations.

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Content

Theory

In plates 2 to 6 it is theoretically shown that at scales above the cloud depth the structure of LWC and LWP should be identical and at scales below the cloud depth LWP is smoother than LWC.

Measurements

We have found a scale break in the power spectrum of high-resolution Liquid Water Path (LWP) measurements. The measurements were made with the microwave radiometer MICCY, which has an integration time of 1 second and a beam width of less than 1 degree, see plates 7 to 9.

2

Theoretical LWP spectra

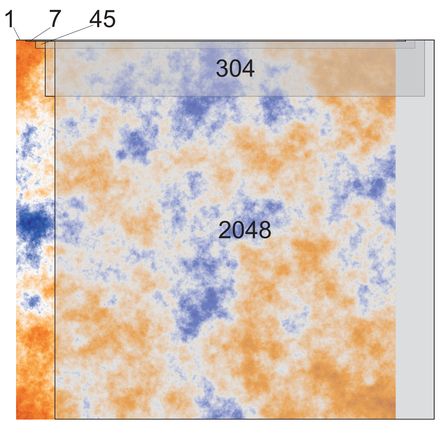
To study the difference between the LWC and LWP structure theoretically, we have made vertical 2D isotropic LWC fields. These fields are 2048x2048 pixels in size. From these fields, we have cut out clouds of varying depth: 1, 7, 45, 304 and 2048 pixel deep (plate 3), and averaged them to get LWP time series, see plate 4.

The power spectra of LWC fields with a power spectrum proportional to k^{-2} is shown in plate 5. The log-log power spectrum without averaging (for the 1 pixel deep cloud) the slope of the LWC field: -2. The others have a scale-break. This scale break is at larger scales for the deeper clouds, but not exactly at larger scales than the cloud depth. At small scales the slope of the LWP spectra is about -2.9.

The relation between the slope of the LWC field and its LWP time series is shown in plate 6.

3

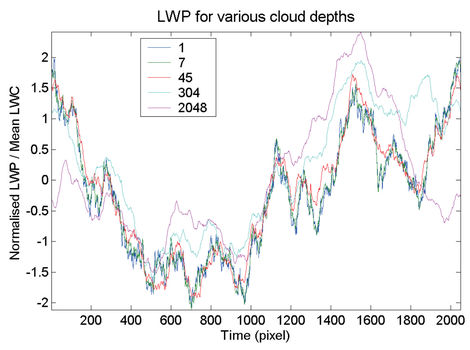
Calculation LWP time series



4

Example LWP time series

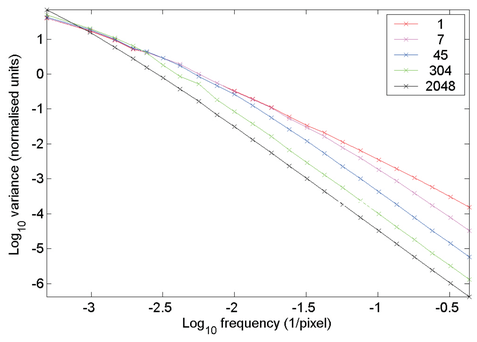
LWP time series for 5 different cloud depths: 1, 7, 45, 304 & 2048. All have about the same variance, but the thin ones are smoother.



5

LWP power spectra, fractal LWC field

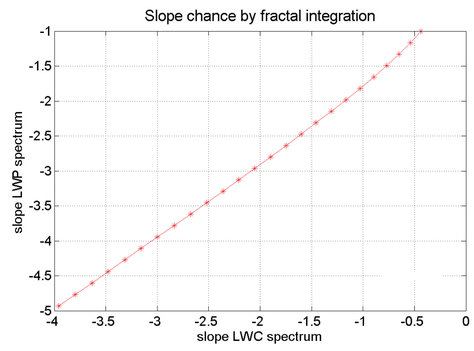
The normalised power spectra of the LWP time series for 5 different cloud depths: 1, 7, 45, 304 & 2048.



6

Relation slope LWC and LWP

The slope of the log-log power spectra of the LWC field and its corresponding slope of the LWP spectrum.



7

LWP measurements

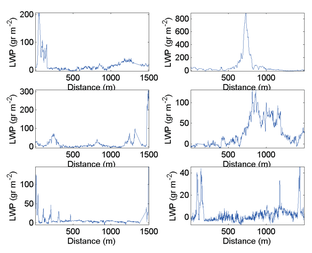
We have found a scale break in the power spectrum of high-resolution Liquid Water Path (LWP) measurements. These measurements were made with the microwave radiometer MICCY, which has an integration time of 1 second and a unique beam width of less than 1 degree. The measurements were made during the BBC campaign which was held in 2001 in Cabauw, The Netherlands.

	MICCY
Antenna beam width	< 0.9
Beam width at 2 km	35 m
Temporal resolution	0.1 s
Maximum range	15 km (horizontally)

8

LWP measurements

For this study, we used 36 quality-controlled time series of half an hour. This plate shows some example measurements. Radar and lidar measurements were used to guarantee that no rain or mixed clouds were present. Cloud free cases were not used. After scaling the time series from time to space by the wind speed from radiosondes, their power spectra were computed and averaged, see next plate.



9

Measured LWP power spectrum

The averaged and binned power spectrum clearly shows a scale break. Were the power law exponent of the larger scales is around -1.1 and the exponent at smaller scales is -1.9. The exponent varies strongly from case to case. The slope above the scale break is not reliable as we have too little scales above the scale break for an accurate estimate.